

**NASA'S NEW ORBITAL SPACE PLANE:
"A BRIDGE TO THE FUTURE"**

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“Although the hours and hours of practice we had hoped to obtain finally dwindled down to about two minutes, we were very much pleased with the general results of the trip, for setting out as we did, with almost revolutionary theories on many points, and an entirely untried form of machine, we considered it quite a point to be able to return without having our pet theories knocked in the head by the hard logic of experience, and our own brains dashed out in the bargain.”

-Wilbur Wright

Abstract

NASA is developing a new spacecraft system called the Orbital Space Plane (OSP). The OSP will be launched on an expendable launch vehicle and serve to augment the shuttle in support of the International Space Station by transporting astronauts to and from the International Space Station and by providing a crew rescue system.

Introduction: A Bridge to the Future

Emerging after 100 years of powered flight, the Orbital Space Plane system portends to be "a bridge to the future" as we cross into the next 100 years of science and technology advancement.

In keeping with the AIAA's theme for the International Air and Space Symposium and Exposition - *The Next 100 Years* - it is believed that the OSP system will contribute to the next 100 years of aerospace in the following ways:

- By improving safety, reducing risk, and minimizing cost of space transportation
- By providing versatility of space transportation:
 - Crew Rescue/Return/Transfer
 - Assured access and logistical support to the International Space Station

Before we explore some of the vehicle concepts for NASA's new OSP, we will first address the need and supporting rationale for such a system, key system requirements, and the development approach which includes the system design philosophy, the acquisition strategy and the role of Flight Demonstrations.

1.0 NASA's Need for a New Space System

The Shuttle fleet has been central to the U.S. space program for three decades. The fleet has flown over 100 missions - and given the complexity of human space flight - it has achieved much and has performed remarkably well. In addition to providing routine access to space, it has served as the platform for human-related space activities and has provided logistical support and access to the International Space Station (ISS).

There are, however, issues associated with the Shuttle fleet, which provide a basis in support of a new OSP system that would *supplement* the existing fleet. First, shuttle operational costs are high due to the fact that the Shuttle was not designed for rapid turnaround intervals between flights. Second, the shuttle program has suffered two catastrophic accidents during missions. For these reasons, it is evident that a safer, more reliable, and economical system is desired by the agency.

Moreover, the existence of the ISS further underscores the necessity for an OSP system. Given that the United States has invested billions of dollars in the ISS, it is crucial for the agency to have a more functional, integrated space transportation system that can:

- Perform cargo transport and logistics missions in support of ISS;
- Provide crew transfer/rescue to and from ISS;
- Provide *assured access* to ISS.

As an integrated space transportation system, the shuttle and the OSP would provide a system safer and less costly to operate than the current shuttle system. Also, the integrated system would offer more functionality. The shuttle would specifically be needed for the cargo and logistics missions due to its large payload capability, while the crew missions would be transitioned to the newer, OSP system. Since the ISS partners are studying options to increase the ISS permanent crew size from three to as many seven, there will be a need to have another vehicle beyond the existing Russian Soyuz (which holds three) for emergency rescue. The OSP, with a minimum crew capacity of four would supplement the Soyuz by providing an additional means of rescue/return by 2010.

Note: Assured access refers to the assurance of obtaining access to the ISS whenever required. To achieve assured access, the need exists for one or more vehicles or systems, with Station docking capabilities, to be available at any given time. For example, if the entire Shuttle fleet were grounded, the OSP would provide an alternate means to station.

2.0 OSP Key Requirements

The agency has established a clear objective for the Orbital Space Plane - to provide a crew transfer and rescue/return vehicle within the next 10 years.

OSP is to provide crew rescue capability to the International Space Station by 2010. In addition, the system shall provide transportation capability for no fewer than four crew to and from the ISS no later than 2012. The risk of loss of crew shall be, with high confidence, lower than the Space Shuttle for the transport mission. Further, Compared with the Space Shuttle, the system will require less time to prepare and execute a mission and have increased launch probability. The availability for the system to be able to perform a mission must be greater than 95%.

The system, which may include multiple vehicle types (systems for crew rescue and crew transport could be different versions of the same vehicle design), shall initially be launched on an Expendable Launch Vehicle (ELV) such as a Delta IV or an Atlas 5. The system shall be operated through at least 2020; however, the system should be designed so that it could be operated for a longer time if necessary. The system shall provide contingency capability for cargo delivery to or from the Space Station to support a minimal level of science. And finally, The system shall support a nominal Space Station crew rotation period of 4-6 months.

3.0 OSP Development Approach

The OSP Development Approach consists of three key elements that focus on reducing the risk associated with new system development while controlling cost and schedule. First, the OSP Design Philosophy emphasizes simplicity in technical design and interfaces in order to reduce risk, and control cost and schedule. Second, the acquisition strategy encourages competition among multiple prime contractors to perform within Program cost and schedule goals. And third, Flight Demonstrations reduces risk through manufacturing, test and analyses of system developments.

3.1 OSP Design Philosophy

OSP Program managers have embraced a design philosophy centering on a holistic systems approach, which emphasizes simplicity throughout the OSP system. Specifically, the design philosophy states:

"We are designing an entire system, not just a spacecraft. We are designing for complete operations. We will eliminate, minimize, or simplify all interfaces. We will manage the requirements and system design with currently available technology to meet Program schedule and cost goals. We are designing the total system for simplicity, even if some flight components become heavier or more complex. We are each responsible for looking at the entire system, asking the right questions, and minimizing system complexity and cost."

When considering this design philosophy, one is reminded of Occam's razor. Occam's razor is the principle attributed to the 14th century logician and Franciscan friar, William of Occam. The principle states, "Entities should not be multiplied unnecessarily", or often interpreted and cited in another form, "If you have two equally likely solutions, pick the simplest."

It is the hope that by maintaining total system simplicity and minimizing interfaces and new technology when possible, the OSP Program may use the razor to cut away unnecessary development risk and costs.

3.2 OSP Acquisition Strategy & Development Timeframe

The first two years of the development timeframe is devoted to a conceptual design period of the OSP system, where the agency plans to retain competition among three prime contractors and their respective designs (see section 3.2.1 "OSP Contractor Teams"). By utilizing an acquisition strategy where multiple prime contractors are tasked to produce system concepts and designs, the agency has created a spirit of competition, thereby launching the "Space Plane Race". After the 2-year design period, the agency plans to make a full-scale development decision, at which time it will decide

which system design meets the agency's needs. The agency may then down-select from its 3 contractor teams to a single contractor team to go forward with the full-scale development of the OSP system. The estimated duration for full-scale development is approximately 6 years. Full-scale development will include a continuation of the design period with a Preliminary Design Review occurring in 2005, and a Critical Design Review occurring in 2007. With some overlapping of the design period, fabrication, assembly, integration and testing of system hardware and infrastructure would occur. By 2010, we would see the flight of OSP with its initial crew rescue capability. At this time, an estimated additional 2 years would be required to man-rate the system to achieve the crew transfer capability. Figure 2.2-1 summarizes the OSP system development timeframe and depicts the first OSP Rescue/Return flight and the first flight with the Crew Transfer capability.

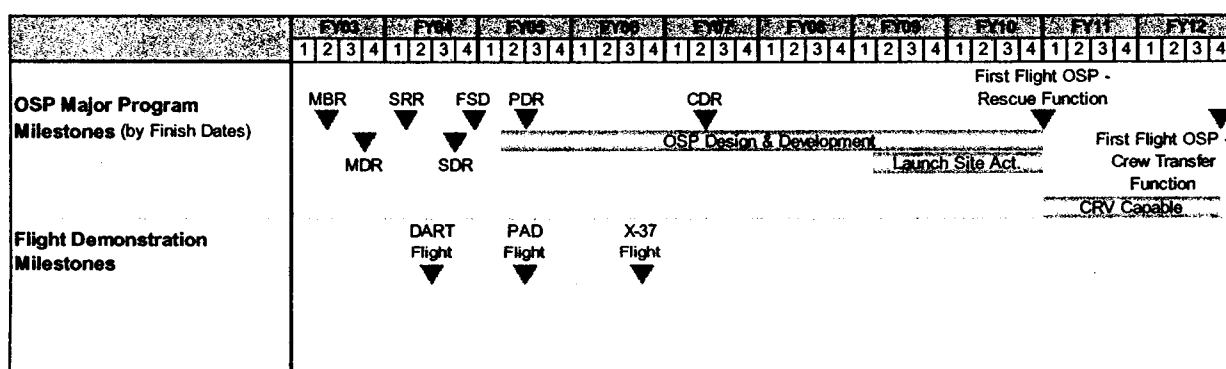


Figure 2.2-1

NASA believes that the schedule is achievable because of a design philosophy that emphasizes simplicity. Furthermore, due to the competitive strategy set forth by the agency, there is a strong incentive among the contractor teams to perform within the OSP cost and schedule goals.

3.2.1 OSP Contractor Teams

The OSP Concept Contractor Teams are:

- Lockheed Martin Corporation; Denver, Colorado
- Boeing Company; Huntington Beach, California
- Northrop Grumman; El Segundo, California, teamed with Orbital Sciences Corporation; Dulles, Virginia

3.3 Role of Flight Demonstrations in OSP Development Approach

Flight Demonstrations will play a central role in reducing risk associated with the development of the OSP system. The primary purpose of the OSP Flight Demonstrations Program is to prove out the developments required for an OSP system through manufacturing, analyses, and test. The current Flight Demonstrations Office consists of three project offices and their respective prime contractors:

- X-37 Advanced Technology Demonstrator - Boeing Company
- Demonstration of Autonomous Rendezvous Technology (DART) - Orbital Science Corporation
- Pad Abort Demonstrator (PAD) - Lockheed Martin Corporation

3.3.1 X-37 Advanced Technology Demonstrator

X-37 will provide a testbed to demonstrate key space transportation advanced developments in real-world environments and increase/advance technology readiness levels. The X-37 subscale space plane will reduce the risk of developing a full-scale Orbital Space Plane by validating data for increased confidence in avionics, airframes, thermal protection system, and operations. The X-37 Project includes collecting critical information in both atmospheric and orbital flight phases. The X-37 will be launched by an ELV and land on a conventional runway. See figure 3.3.1-1 for an illustration of the X-37.

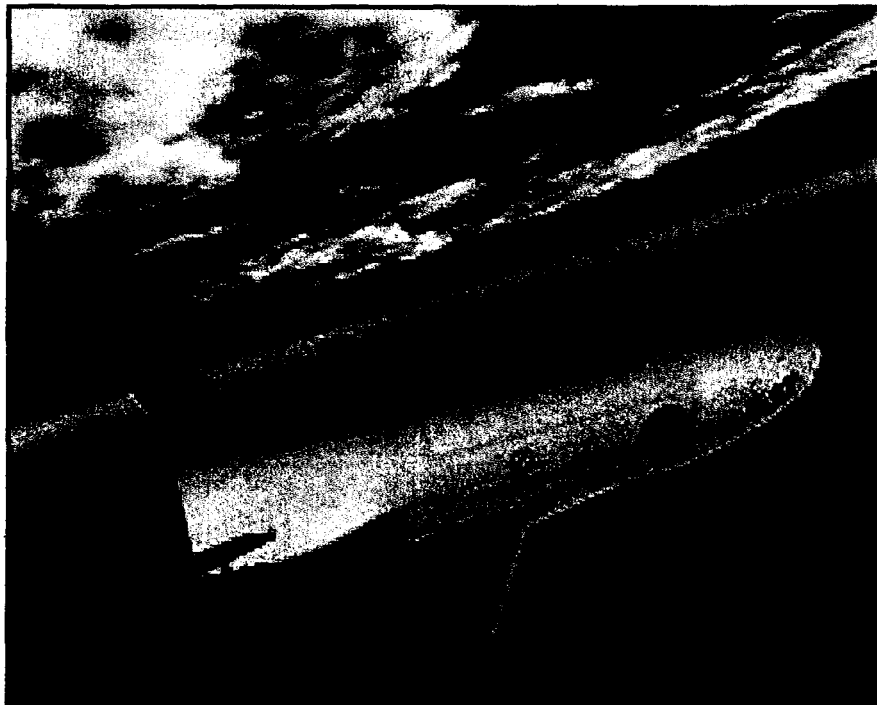


Figure 3.3.1-1

3.3.2 Demonstration of Autonomous Rendezvous Technology (DART)

The Demonstration of Autonomous (DART) chase vehicle will be launched on a Pegasus expendable rocket to demonstrate rendezvous and proximity operations in space. The DART vehicle will use the latest Advanced Video Guidance Sensor (AVGS) technology to come close to a target satellite called the MUBLCOM. As the DART vehicle closes in on the MUBCLOM satellite (to approximately 50 ft), the vehicle will perform a series of maneuvers to test Autonomous Rendezvous and Proximity Operations (ARPO). This flight phase will validate ground test results and algorithms. Raising key technology readiness levels will reduce the risk of developing new ISS servicing capabilities. DART will demonstrate autonomous rendezvous technology in conjunction with an Advanced Video Guidance Sensor (AVGS) and Autonomous Rendezvous and Proximity Operations (ARPO) software. See figure 3.3.2-1 for an illustration of the DART project.



Figure 3.3.2-1

3.3.3 Pad Abort Demonstrator (PAD)

PAD will serve as a risk reducing agent for OSP by validating crew escape technologies for future crew escape systems. The system will focus on requirements associated with system safety, loss of crew, crew escape, and launch pad abort.

PAD is a reusable system, which will employ mannequins outfitted with instrumentation to gather data on crew environments during demonstration of crew escape propulsion systems, parachute deployment, vehicle orientation and landing techniques, and external aeroshell configurations. See figure 3.3.3-1 for an illustration of the PAD Demonstrator.

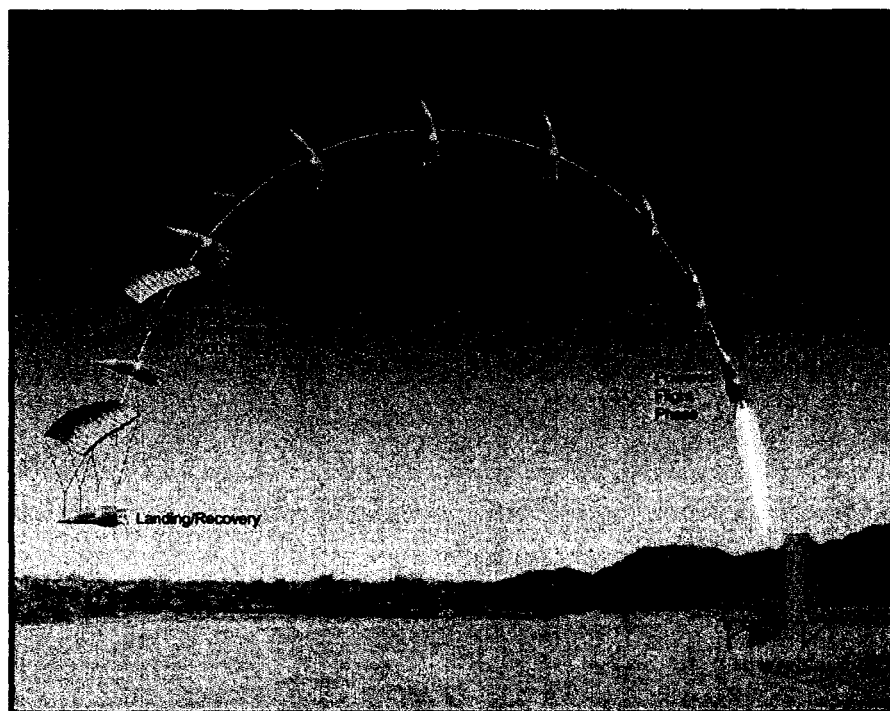


Figure 3.3.3-1

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4.0 OSP Vehicle Concepts

At this point in the OSP development, the concept development trade space remains open. NASA is considering vehicle options ranging from Apollo-type capsules to winged and/or lifting body vehicles. In this section, we will first discuss the aspect of improved safety and crew escape as it relates to the OSP, then review the concepts while considering some pros and cons associated with each. Data specifically pertaining to vehicle characteristics has been approximated to protect proprietary interests of the competing contractors, while still providing useful information.

4.1 Improved Safety and OSP Crew Escape

Crew safety and escape are paramount focuses of the OSP development. The OSP requirement that the system have a lower risk of loss of crew than the shuttle drives the system concepts. As with the vehicle concepts, the crew safety and escape concepts trade space is broad and must address all phases of the mission including: ascent, on-orbit, reentry and landing. NASA is considering ejection seats; escape pods, and intact aborts among other ideas as aspects of the overall OSP safety and crew escape.

Intact abort is preferable but requires the ability of the vehicle to separate and fly away from the ELV stack during an emergency situation during ascent. This then requires: (1) sufficient warning time of an anomaly, (2) the ability to accelerate away from the stack, and (3) a flight range sufficient to land at an emergency runway. Of course, when the anomaly occurs has direct bearing on the difficulty of doing the above. However, in any case, the task of developing the system is complex.

Ejection seats offer limited but valuable escape advantages. Over a small part of the flight regime (about 100K ft), ejection seats are credible. However, their most valuable contribution is for on-pad use. Ejection seats are envisioned as a possible way of getting a crew away from a catastrophic situation with the ELV-OSP stack on the ground.

Pods offer crew escape coverage possibly over the entire flight regime. Pods can come in several types including: interior protected volumes, which would be ejected, clear of the OSP vehicle, and exterior "pull-away" volumes which accelerate away from the remaining vehicle portion. See figure 4.1-1 for an illustration of Crew Escape options.

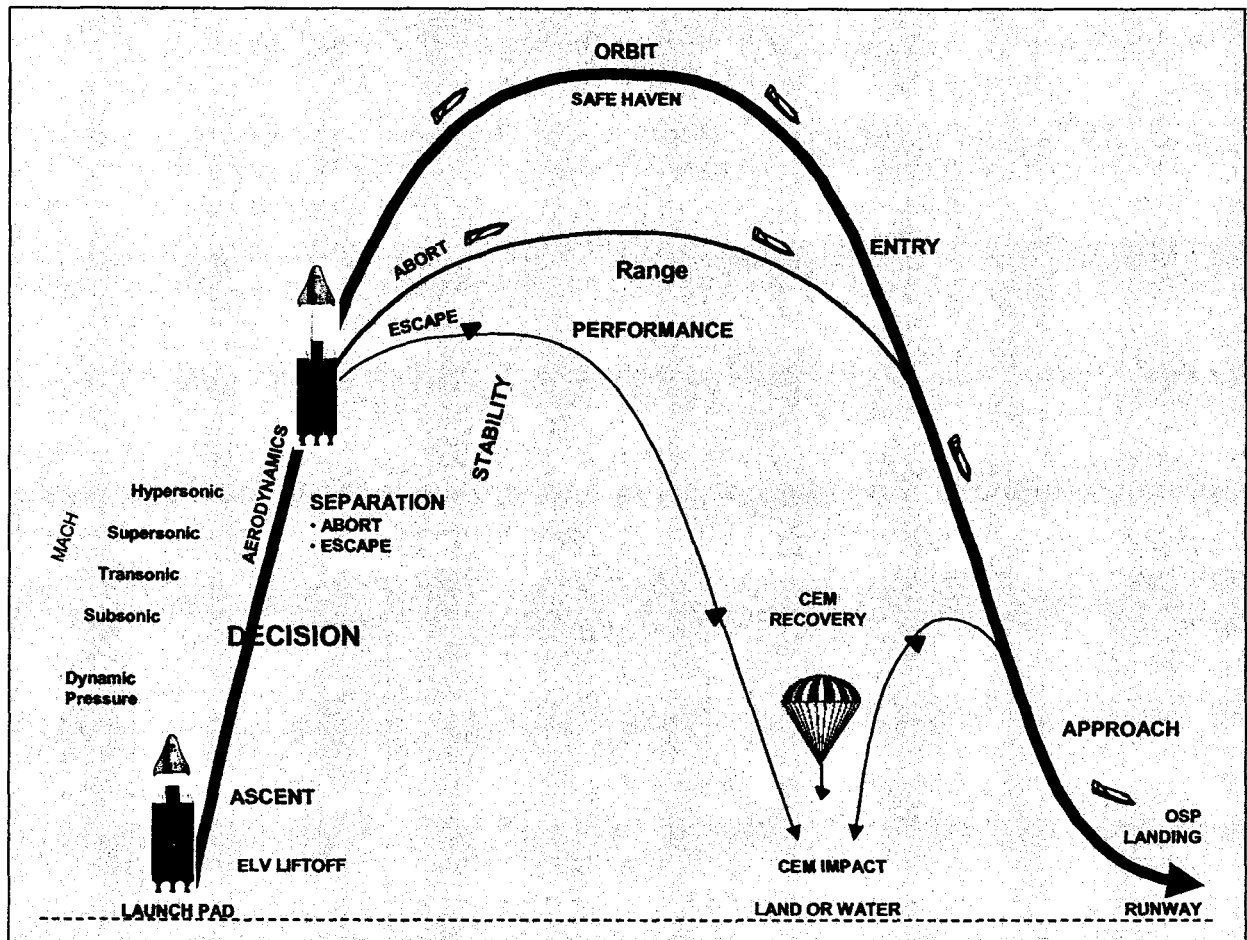


Figure 4.1-1

4.2 Capsules

Capsules are small, axisymmetric vehicles, which allow for straightforward integration with an ELV that especially supports their early use as rescue vehicles. The capsule can be mounted on top of an ELV much like a normal payload and deposited at ISS. The capsule can then be attached to the ISS until such time as it is required for crew return. Capsules are relatively unsophisticated vehicles and thus will cost less and require less time to develop.

Capsules can be inserted into other vehicles, for instance a winged body, and flown. This approach allows for the development of a crew rescue vehicle first, then a capsule within (or attached to the front of) a larger spacecraft for routine crew transport to and from ISS. This system offers an obvious crew-escape advantage in that the capsule can be configured as an escape pod. A possible drawback to this combined system is that the system *may* have to be able to support crew system override capability from an inserted (or attached) capsule. However, the larger vehicle would still be capable of autonomous flight. One can also see complications of a fully stacked ELV-Space Vehicle – Capsule

system and the required control allocations between the three pieces. It is not an impossible task to develop this system, just a challenging one.

A distinct disadvantage to a capsule concept is the limited cross-range of the vehicle and the way the vehicle lands. In emergency situations such as a crew injury, the capsule can get away from the ISS quickly but will likely not have the maneuverability to land near existing medical facilities; although, medical facilities can come to it. But the latter complicates the overall system and has associated cost. Also, the capsule may land "abruptly" which may be hard on an injured crewmember. See figure 4.2-1 for an illustration of a capsule concept.

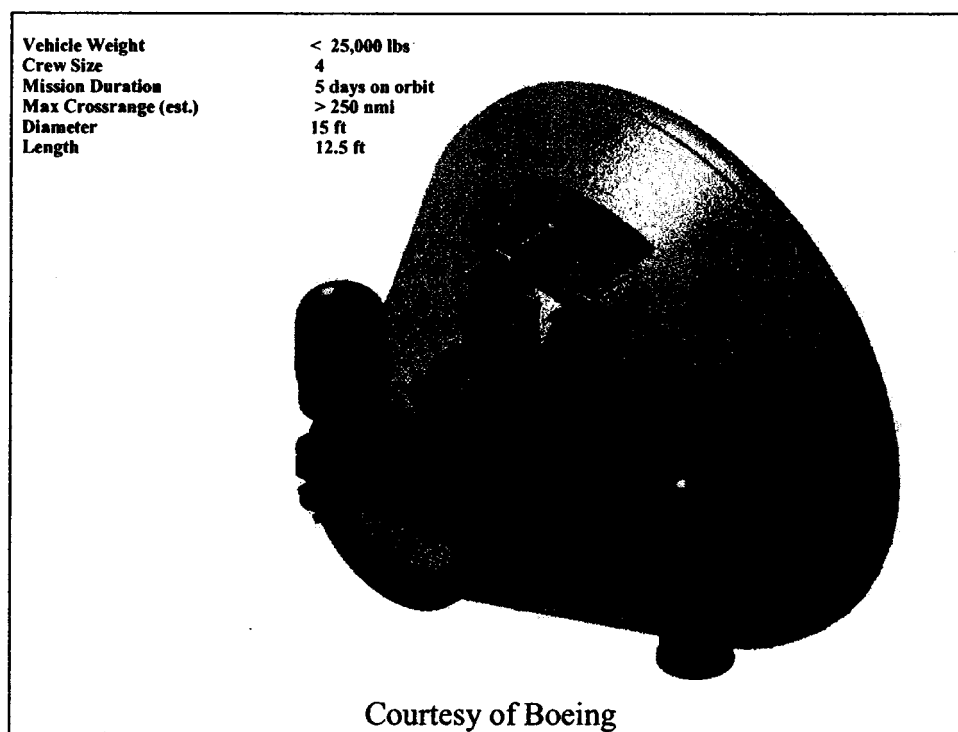


Figure 4.2-1

4.3 Winged Vehicles

Winged vehicles (WVs) are larger and more capable vehicles. In fact, it will be a challenge to design a WV small enough to ride on top of an ELV stack. NASA has looked at preliminary weights and deduced that we can stay within the weight capability of larger (50K lbm payload capacity) ELV systems. That is only part of the issue with the ELV; NASA is currently assessing control authority, dynamic loading, and other considerations.

WVs offer increased maneuverability (a function of the Delta IV, hence a design requirement), increased cross range (> 1000 nm), ability to scale a vehicle in an

understood manner given that the aerodynamic characteristics of one scale is known, and a legacy to NASA's shuttle (an understanding and experience with these type vehicles). Please refer to figure 4.3-1 for cross range values of various vehicles.

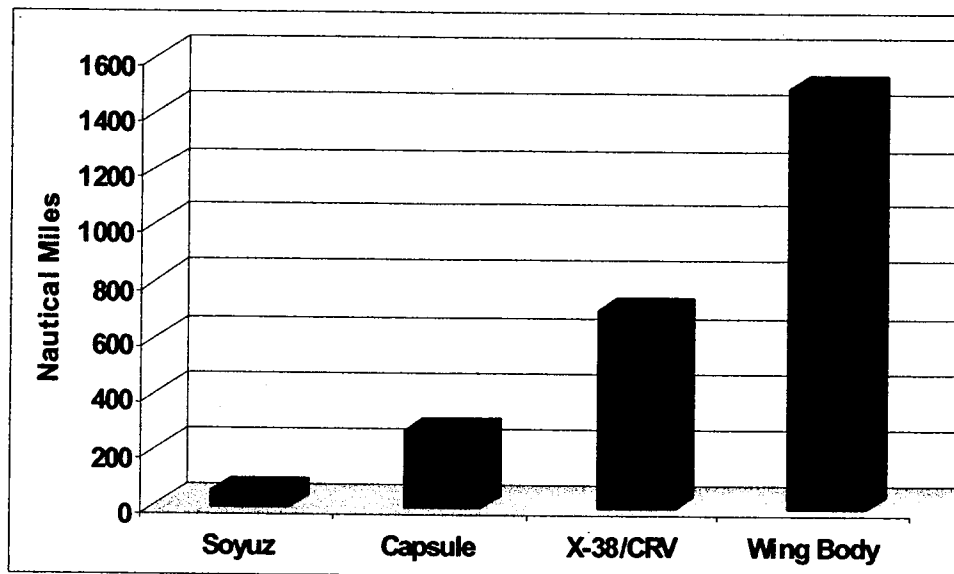


Figure 4.3-1

The WVs offer more capability than a capsule, therefore it may be more of a challenge to stay within Program cost and schedule goals associated with development. See figures 4.3-2 and 4.3-3 for illustrations of Winged Vehicle concepts.

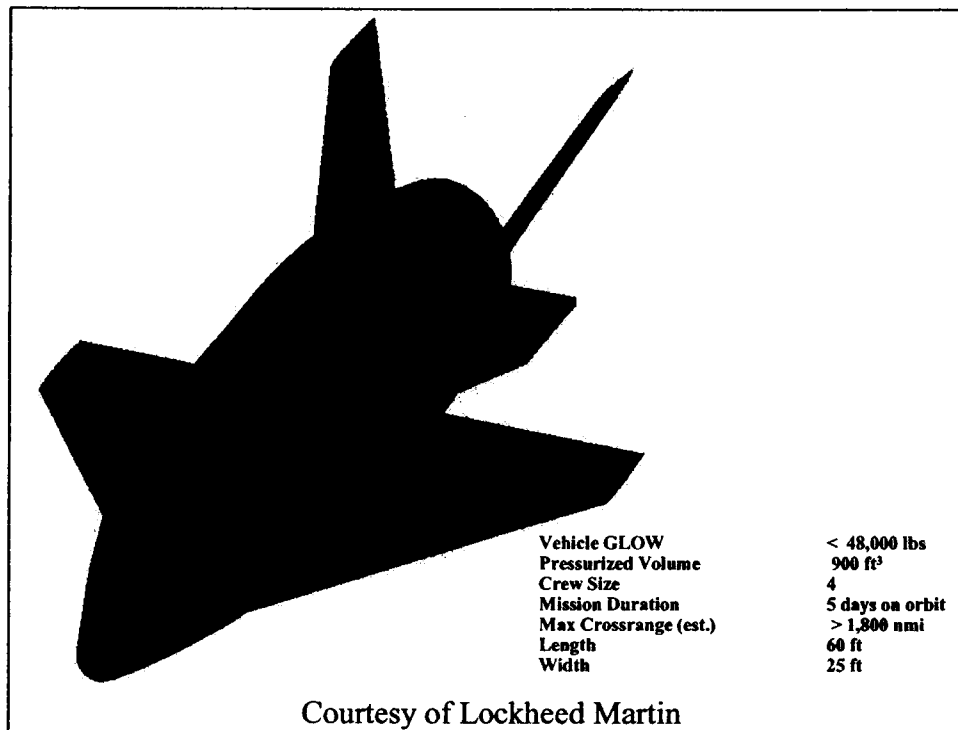


Figure 4.3-2

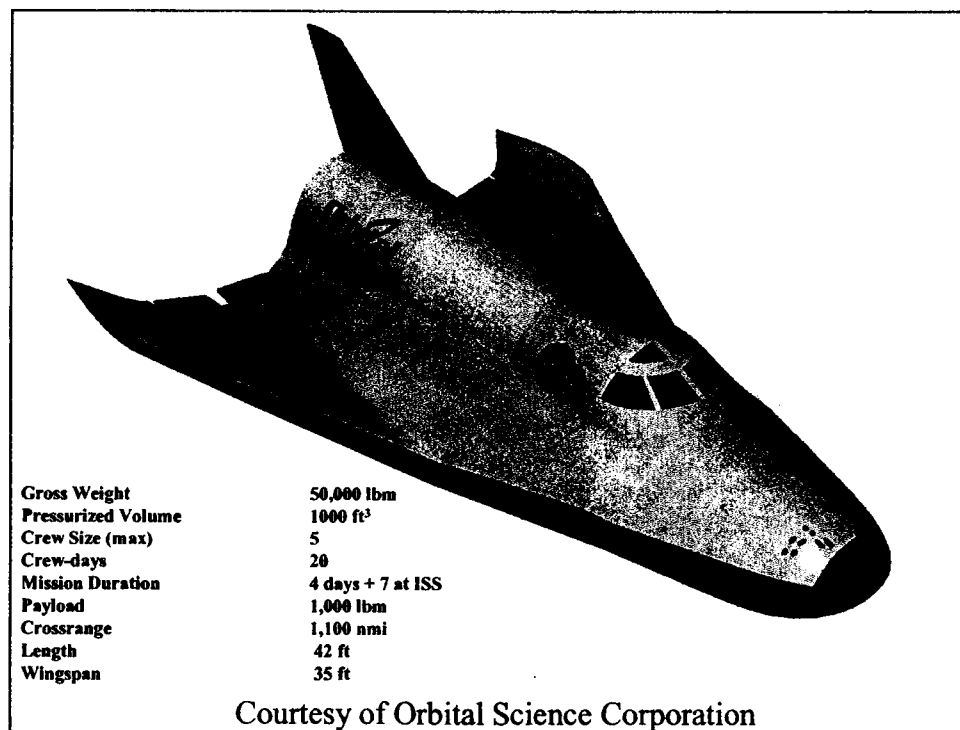


Figure 4.3-3

4.4 Other Concept Considerations

Lifting Bodies, often combined with winged concepts, are under consideration by NASA. This approach offers much of the same benefits as a WV, but the ability to scale up is less straightforward. Lifting bodies employ a more complicated shape, particularly on the belly of the fuselage, thus a more difficult scaling task.

NASA has decided to design to technology, which will be readily available in the next one to two years. Therefore, advanced shape concepts requiring technologies, such as ultra-advanced thermal protection (capable of 3000 to 5000 deg performance), are not in consideration.

5.0 Conclusion

We began this paper with a quote from Wilbur Wright. Although our undertaking is different, the boldness is much the same. Wilbur and his brother, Orville, were determined to succeed with their ideas for flight through application of theory, hard work and tenacious belief. Likewise, we at NASA are determined to develop an OSP that will be a bridge to the future, inaugurating another 100 years of exploration. The system will be safer, more reliable, and less costly; thus preparing the way for routine flight.